

# EXHIBIT 1



December 18, 2018

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## **THE BLUFFS AT EVERGREEN FIRE INVESTIGATION REPORT**

Insured: DH&G LLC  
Loss Location: 2 West Casino Rd.  
Everett, WA 98204  
Date of Loss: December 31, 2015  
File Number: 220.19486  
JH File Number: 1C0703257

JENSEN HUGHES was retained on January 6, 2016 and requested to investigate the origin and cause of a December 31, 2015 fire at the Bluffs at Evergreen apartment complex, located at 2 West Casino Rd., Everett, WA 98204.

At your request, JENSEN HUGHES has prepared this report regarding our fire origin and cause investigation to date. This investigation was conducted in accordance with the guidelines set forth by *NFPA 921: Guide for Fire & Explosion Investigations*.

### **SCOPE OF INVESTIGATION**

The scope of our investigation included the following:

1. JENSEN HUGHES Senior Fire Investigator Ken Rice conducted an initial fire scene examination on January 7-8, 2016.
2. JENSEN HUGHES Senior Architect Jeff Harris performed a structural damage examination of the fire damage building on January 1, 2015, along with Investigator Rice.
3. JENSEN HUGHES Senior Electrical Engineer Sebastian Scheiff, JENSEN HUGHES Evidence Technician Eric Encell and Investigator Rice examined the loss site and recovered evidence on January 19-20, 2016.
4. Engineer Scheiff conducted a joint-party laboratory evidence examination on August 25, 2016.
5. JENSEN HUGHES Senior Electrical Engineer Daren Slee conducted a joint-party laboratory evidence examination of the subject laptop and associated components on March 20, 2017.
6. Engineer Slee conducted a joint-party laboratory evidence examination of the remains of the battery pack from the subject laptop on August 2, 2017.
7. JENSEN HUGHES Senior Electrical Engineer Andrew Paris nondestructively examined selected evidence items on June 20-21, 2018.
8. Computed Tomography (CT) scans of the subject laptop battery cells.
9. Examinations of exemplar laptops and battery packs.

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10. Investigator Rice interviewed one of the tenants of the apartment of fire origin, Ms. Lynn Yevrovich, in the parking lot of the Bible Baptist Church on January 8, 2016.
11. Researched the design and function of Camel Blue Cigarettes.
12. Obtained and reviewed material received from Public Agencies, including the following:
  - a. Everett Fire Department (EFD) - Incident Number: 2015-00304080
    - i. EFD Incident Report
    - ii. EFD NFIRS<sup>1</sup> Report
    - iii. EFD site photographs
    - iv. 911 call record and audio files
    - v. Emergency Responder CAD Record and radio traffic audio files
    - vi. Video recording of EFD and EPD interview of Lynn Yevrovich
  - b. Everett Police Department
    - i. EPD Compact Case Report (Case Number: 2015-00323266)
    - ii. EPD Incident Report
    - iii. EPD Initial Case Report
    - iv. EPD Case Supplement Report
    - v. EPD Written Statement Form produced by Lynn Yevrovich
13. Reviewed documents received from the Bluffs at Evergreen management, including:
  - a. Floor Plans, Apartment Inspection Reports, Resident Applications, Move-In/Move-Out Reports, Lease Agreements and Addendums, Work Orders, Resident List(s), etc.
14. Reviewed documents from the Home Shopping Network regarding the subject laptop computer.
15. Reviewed and researched various technical reports, data, papers, etc. including, but not limited to:
  - a. NFPA 921: Guide for Fire & Explosion Investigations
  - b. Lithium-Ion Batteries Hazard and Use Assessment<sup>2</sup>
  - c. Ignition Handbook<sup>3</sup>
  - d. Various other articles, papers, data, texts, etc., some of which are referenced in this report.
16. Researched applicable standards, and local and state codes.
17. Reviewed local news articles and media reports
18. Reviewed social media photographs and videos of the fire.

## SUMMARY OF FINDINGS

### Property Description

The Bluffs at Evergreen was a residential apartment complex in Everett, Washington built in 1969 and last remodeled in 2007. The complex included an office building and 217 rental units dispersed among eight apartment buildings. Each three-story apartment building was built with wood-frame construction and contained a composition roof. The apartments contained exterior entrances accessed by covered walkways. Each unit shared an exterior hallway and vestibule with an adjoining apartment.

The fire originated in Unit E101 in Building E, a three-story, 9,758 sqft, apartment building with 30 units. The long axis of the building was situated east-west (Figure 1). Unit E101 was a 921 sqft, two-bedroom apartment located on the west end of the second floor. Unit E101 contained a kitchen, dining room, living room, one full-sized bathroom, and two bedrooms. A diagram of Unit E101 is shown in Figure 2, and a detailed diagram of the southeast bedroom is shown in Figure 3.

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<sup>1</sup> National Fire Incident Reporting System.

<sup>2</sup> Kahn, Michael, et al. *Lithium-Ion Batteries Hazard and Use Assessment*. Exponent Failure Analysis Associates, Inc. Jul. 2011.

<sup>3</sup> Babrauskas, Vytenis. *Ignition Handbook*. Issaquah: Fire Science Publishers, 2003.

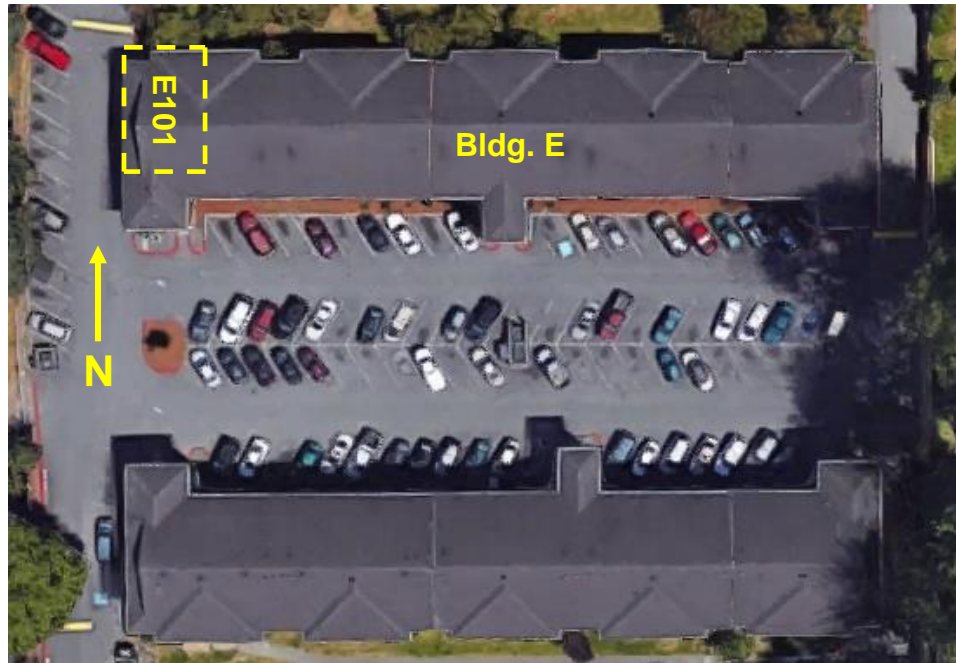


Figure 1: Aerial view of Building E with Apt. E101 noted.

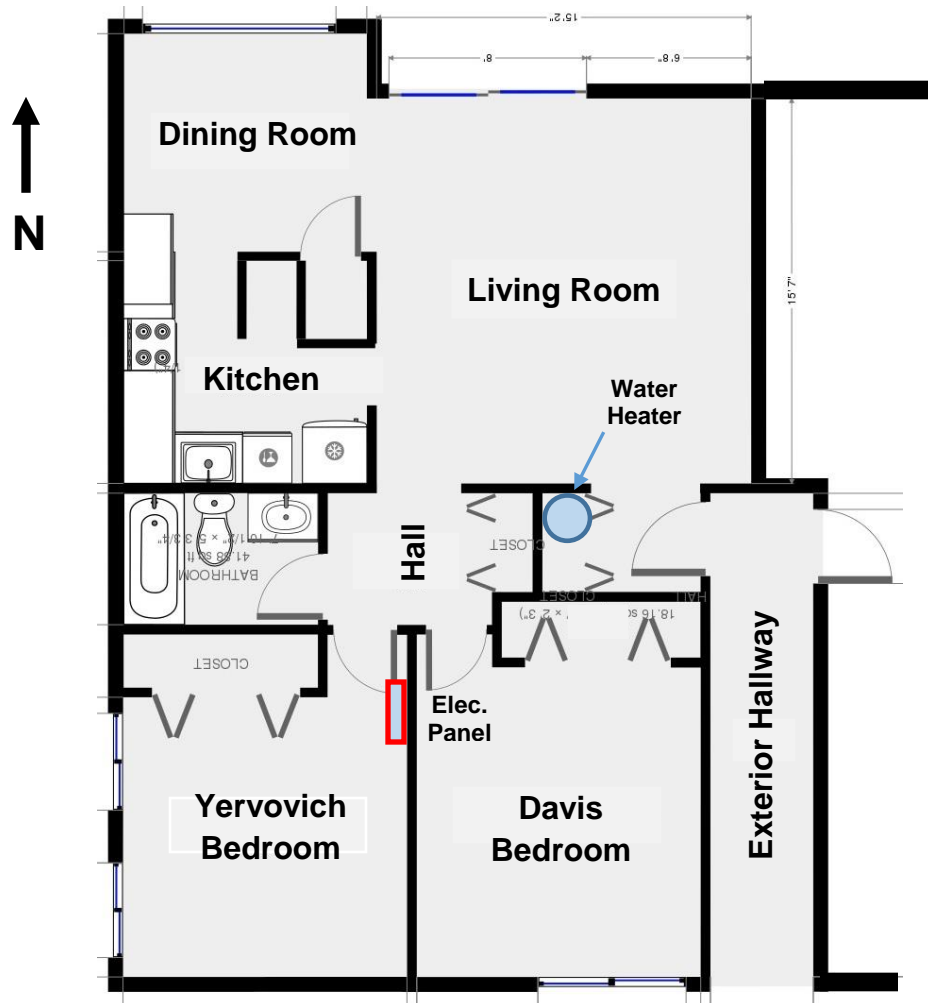
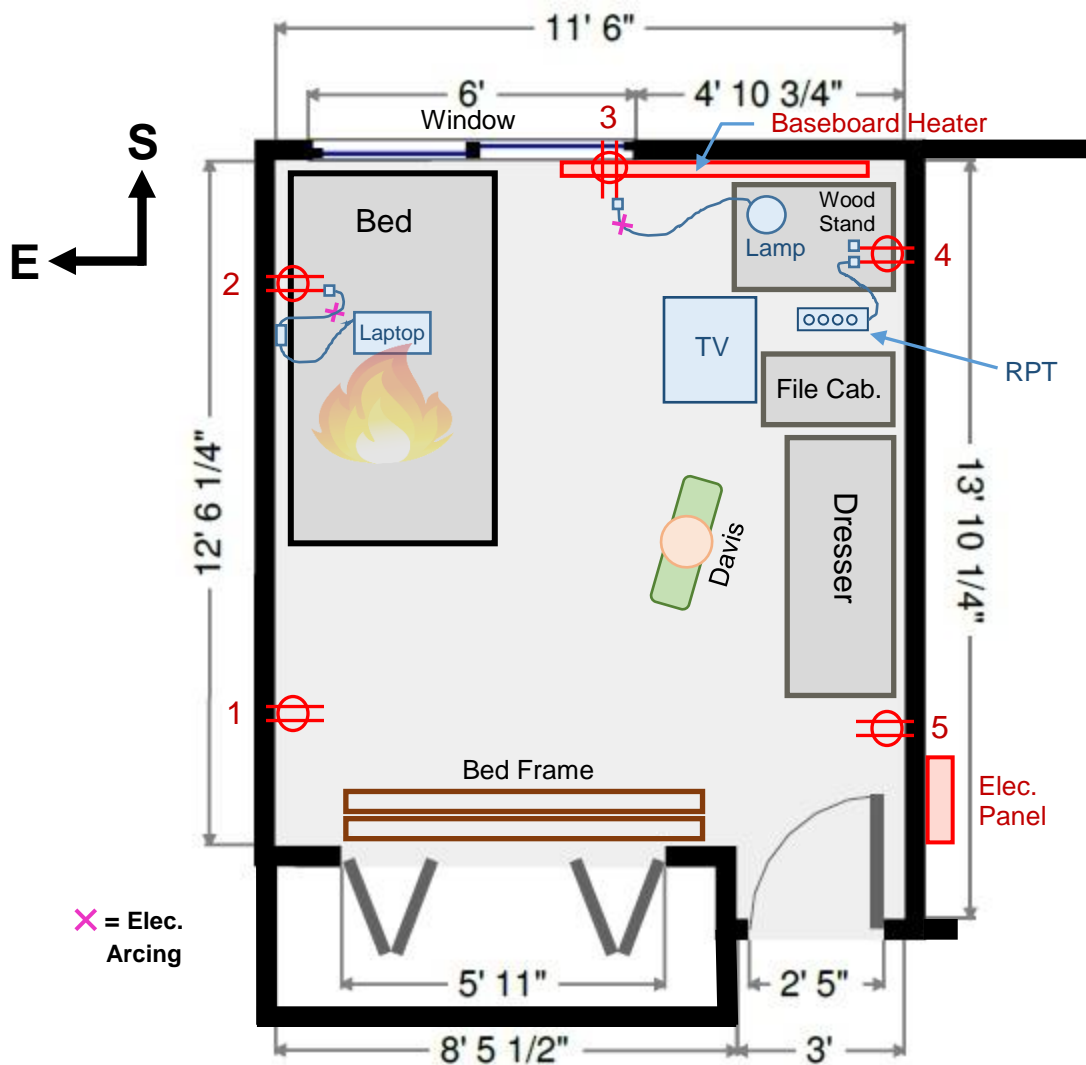


Figure 2: Diagram of Apartment E101.



**Figure 3: Apt. E101, Davis Bedroom (SE bedroom) at the time the fire was discovered. Room dimensions accurate, contents not to scale.**

Utilities: The local electrical utility provided 120/140V electrical service to Building E through 75-kVA pad-mounted transformers at the southwest and southeast corners of the building. Service entrance conductors traveled to electrical switchgear in two main floor Utility Rooms. Main service disconnects in the Utility Rooms fed multi-unit residential meter stacks, and each apartment was individually metered and protected by a 125A circuit breaker. Feeder conductors traveled from service disconnects to individual Zinsco brand feeder panels in each apartment. Apartment E101 was fed from a meter stack in the southwest Utility Room.

The apartments did not have natural gas service. There were no fire sprinkler systems within the complex, nor was there an automatic fire alarm system. Each apartment unit contained local, battery-powered smoke and carbon monoxide alarms.

### Background Information

Lynn Yevrovich and Mark Davis moved into Apartment E101 on January 1, 2013. In October 2015, Mr. Davis and Ms. Yevrovich renewed their lease through the end of 2016. The move in/out checklist and work order documents provided by Evergreen Apartment management showed miscellaneous repairs to Apartment E101 from January

2013 to the time of the fire. Electrical system repairs included the replacement of receptacles in the kitchen and living room in 2013.

### Fire Sequence of Events

Information regarding the fire's sequence of events was provided by the Everett Fire Department and Everett Police Department records, and through an interview(s) with Lynn Yevrovich, the surviving tenant from the apartment of fire origin, Apartment E101. Information regarding the fire's sequence of events taken from the various sources of information are summarized below.

JENSEN HUGHES' Lynn Yevrovich Interview: Senior Fire Investigator Ken Rice interviewed Ms. Lynn Yevrovich in the parking lot of The Bible Baptist Church on Casino Road in Everett, Washington on January 8, 2016, and she provided the following information:

- She and Mark Davis lived in the unit as boyfriend and girlfriend.
- They were in the living room watching TV on the day of the fire when she told him she wanted to leave him (end their relationship). He told her "Fuck You" and went into his bedroom.
- She was watching Big Bang Theory when she smelled smoke approximately 1 to 1.5 hours later. It was definitely not cigarette smoke.
- She opened Mark's door and saw him standing in the middle of the bedroom. He was wearing a black, down (filled) coat. There was a fire on the mattress near the computer. She yelled at Mark to get out, but he just stood there and would not leave. He was standing west of the bed, closer to the west wall.
- She called 911 from the cordless landline phone in the apartment.
- The smoke was white, then it turned black and filled the room as the fire grew.
- The fire spread across the bed and up to the ceiling.
- The smoke alarm went off within 1-2 seconds after she opened the door.
- She tried to go back in after leaving, but it was too hot.
- Mark drank and smoked Camel Blue cigarettes, but he did not smoke in the apartment.
- Lighter fluid that Mark used for his cigarette lighter was possibly in the room.
- Mark recently purchased a new HP brand laptop computer from the Home Shopping Network. He would use it to pay bills and watch videos. The laptop was on his bed.
- The mattress and box spring laid directly on the floor in the southeast corner. There may have been a pile of blankets on the bed.

### EFD NFIRS Report

- The fire was reported to the EFD at 19:10 on December 31, 2015. [Via Ms. Yevrovich's 911 call]
- The EFD arrived at 19:14.
- The fire extended out of Apartment E101 prior to their arrival.
- The EFD rescued multiple people trapped in Building E.

CAD Narrative: The CAD Narrative is a time-stamped listing of notes entered into system by emergency operators. It is a combination of 911 calls, fire department radio traffic, and responder directions/instructions.

- "MATTRESS ON FIRE" – 12/31/15 – 19:09:55.
  - **JH Note:** This was Ms. Yevrovich's first 911 call.
- "ADV TO EVAC, STATED ITS SPREADING" – 12/31/15 – 19:10:10.
  - **JH Note:** Likely interpreted as: "Advised to Evacuate, (she) stated (the fire is) spreading."
- "TRYING TO GET HBD MALE OUT OF LOC" – 12/31/15 – 19:10:25
  - **JH Note:** Apparent reference to Ms. Yevrovich trying to get Mr. Davis out of the apartment.

EFD Incident Report: This report was prepared by EFD Investigator James McCall. Pertinent information in the report included:

- The outside temperature was 32°F with a 6-mph NE wind.
- Mark Davis perished in the fire. He was found in the exterior hallway in the prone position with his head facing north, in-line with the entrances to Apartments E101 and E102.
- The southeast bedroom of Apartment E101 sustained the most fire damage. The bed in the southeast corner was consumed by fire. The fire travelled out the east window and extended upward and outward. Fire eventually spread eastward through the roof structure.
- The remains of a laptop computer were found, and it was determined to have been plugged into the east wall electrical receptacle next to the bed.
- A 4.5-oz can of lighter fluid was found on top of a dresser along the west wall, and an 8-oz can of butane was found in an unburned drawer of the dresser.
- Statements from Lynn Yevrovich were recorded in EFD Incident Report:
  - The fire started on the mattress and the smoke alerted her to the fire.
  - She attempted to get her roommate (Mr. Davis) out of the bedroom.
  - She saw the walls and molding catch fire.
  - A giant black-and-white TV along the west wall didn't work and was used as a coffee table. A nearby table had a small lamp on it that was left on all night.
- Investigator McCall determined that the fire originated in the southeast bedroom, possibly on the mattress in the southeast corner.
- The fire was classified as Undetermined, possible causes included:
  - Careless smoking igniting available combustibles
  - Electrical malfunction igniting available combustibles
  - Flammable liquids in the area of origin contributing to fire load and spread.

EPD Reports and Documents: Multiple EPD Officers prepared Case Reports and other documentation on the fire.

- The documents showed that "Electrical Wiring" was collected as evidence.
  - **JH Note:** These items were later transferred to JENSEN HUGHES (formerly CASE Forensics).
- Officer Ryan Hanks responded to the fire. He spoke to Ms. Yevrovich while he was on site and her statements were noted in his report narrative:
  - She said, "I know my roommate started this fire"
  - Mr. Davis fell asleep earlier with a lit cigarette.
  - Mr. Davis smokes in bed (and) is a safety hazard.
  - Mr. Davis had bought a lot of alcohol that day.
  - She saw a bunch of smoke coming from Mr. Davis' room. She entered the room and saw the mattress on fire. She tried to wake Mr. Davis up, however he was intoxicated and would not get up.
  - She tried to wake him up until the fire spread to the molding and walls. She then ran off on foot and yelled for people to evacuate.
- Lynn Yevrovich prepared a written statement for the EPD on December 31, 2015. It stated:
  - *"Today Doc (Mark Davis) got his SSI money and immediately bought booze, got drunk, and smoked in this [illegible]. I smelled smoke, opened the door to his room. The mattress was on fire and the place was full of smoke. I yelled at him to get out and I called 911 and reported the fire. I yelled at Mark Davis to get out but he wouldn't go. I ran to the rest of the building and yelled for everyone to get out. The apartment where the fire started was E101. Mark lit the mattress on fire."*



- EPD Detective Michael Atwood investigated the fire, examined the fire scene, and interviewed witnesses. His observations and information included:
  - His site investigation determined that the fire originated in the southeast bedroom.
  - The mattress in the southeast bedroom was placed outside the window (by the fire department).<sup>4</sup>
  - There appeared to be no evidence of a crime at the scene. No evidence of drug issues that would cause a fire was found in the residence.
  - A small bottle of butane was found on site.
  - EPD Investigators removed some electrical wiring from a receptacle near the area of fire origin. The evidence was transferred to JENSEN HUGHES (formerly CASE Forensics) on January 19, 2016.
  - The Medical Examiner's Office said Mr. Davis died from inhaling soot and combustion products, and that his death was accidental.
  - He spoke with a Home Shopping Network representative and confirmed the following facts regarding the laptop in Mr. Davis' room.
    - Mr. Davis purchased the HP brand laptop, Model 15-AC13DS, in December 2015.
    - It had a 15.6-inch monitor and was blue in color.
  - He found no evidence of a crime and closed his case file.

EPD & EF Yevrovich Interview: Detective Atwood and EPD Fire Investigator McCall conducted a video-recorded interview with Ms. Yevrovich on January 6, 2016. Her statements during the interview included:

- She and Mr. Mark Davis (aka "Doc") used to be a [romantic] couple, and they had lived together for about five years.
- Mr. Davis was a heavy drinker and was drinking alcohol on the day of the fire. He would often drink and pass out.
- She and Davis were in an argument approximately 1 to 1.5 hours before the fire. She wanted to see other people and get a new job. Davis told her "Fuck you" several times and went to his room. She went to the far end of the living room to watch television.
- About two hours later, she was watching television in the living room when she smelled smoke. She knew it wasn't from a cigarette, so she jumped up out of her chair and ran to the bedroom door where she saw billowing white smoke coming from under and around the door frame.
- She opened the door and saw Davis standing in the middle of the room, approximately 6-7 feet northwest of the mattress. There was a fire on the mattress with flames shooting into the air. He just stood there starting at the fire on the mattress. He never looked at her.
- He was wearing a large down (filled) coat and tattered blue jeans. She noted that he wasn't on the bed and he wasn't on fire. Usually when he passed out from the booze he would be curled up on the bed.
- She called 911 and yelled at Davis to get out of the room, but he was ignoring her. Suddenly, the fire spread out and flared up. Mr. Davis jumped back, went down, and then she couldn't see him anymore. She tried to get him out, but it was too hot and the whole place was filled with black smoke so she couldn't see anything.
- She could hear [him] coughing, and she was also coughing.
- She felt the need to get out of the apartment and she ran out the front door and into the covered walkway. She left the southeast bedroom door open, so Davis could get out, but closed the front door on her way out. Soon this after she saw the windows in the south wall of the southeast bedroom burst out.

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<sup>4</sup> JENSEN HUGHES found the mattress and box spring remains inside the southeast bedroom.



- There was an old, twin-sized box spring and mattress that sat on the floor of his bedroom. There were hardly ever linens on the bed, but there may have been a blanket.
- When she looked in the room, she didn't see anything on the mattress, but the fire caught things around it on fire.
- There was a small lamp that was left on day and night. There was also a giant black-and-white television that didn't work anymore that he used it as a coffee table.
- Davis had a butane lighter that she gave him.
- She thought she smelled cigarette smoke prior to smelling the smoke that she knew was not from a cigarette.
- Davis was a smoker. He would smoke in the bedroom when they had fights. She told him not to, and she told him to smoke on the patio. However, she wasn't [in] there, so she couldn't see [if he did] it.
- He made no noise prior to or during the fire.
- There were no illegal drugs in the apartment. They both occasionally used marijuana.
- There was a new computer in the room that was just bought. The computer always left on the bed.
- She said he may have been overcome with emotion after their fight. She felt he started the fire on accident or purposely.
- Davis was not suicidal.

Lynn Yevrovich 911 Call: The following information and statements are from Lynn Yevrovich's 911 call at 19:09:55 on December 31, 2015:

Of note, a smoke alarm can be heard sounding off throughout the call. Additionally, Ms. Yevrovich was speaking coherently and was not coughing from smoke during the call.

Call Synopsis:

- Operator: "Hello, what's going on there?"
- **00:03** - Yevrovich: "There's a mattress on fire. My housemate just (hit?) the mattress on fire. We've got a big fire here please hurry. Hurry, hurry."
- Operator: "OK, and is it out?"
- Yevrovich: "It's 2 West Casino Road, Apartment E101. Please hurry."
- Operator: "OK and is the box mattress still on fire?"
- **00:19** - Yevrovich: "Yes it's on fire! I don't know what to do."
- Operator: "OK, I need you to get out of the house. Get out of the house."
- **00:23** - Yevrovich: "OK. Come one Doc, you gotta get out of the house! Come on, let's go. Doc you gotta get out. You gotta go. I don't know what to do with him. He's not listening, he's drunk. Oh, I gotta get him outta here."
- *An (unintelligible) male voice can be heard responding to her.*
- Yevrovich: "Doc get outta here now. "We can't, we can't even see. Come on, let's get out of here."
- *Movement and the opening and/or closing of doors can be heard.*
- **00:45** - Yevrovich: "Ow! Sorry, we got, we got out the door. This place is on fire. Please sent somebody"
- Operator: "OK, we've already... (crosstalk) Ma'am I've already got them advised. Is there a fire alarm that you can pull outside?"
- Yevrovich: "(Sighs) I don't know. I'll look."
- Operator (crosstalk): "Make sure you shut the door on your way out, OK? (crosstalk)"
- Yevrovich: "Yea. Shut the door Doc. Shut the door!"
- **01:03** - *The sound of a door closing can be heard, along with an unintelligible male voice responding.*

- Yevrovich: "Come on. Oh man, this has been waiting to happen because he gets drunk all the time. He does stupid things."
- Operator: "That's not what I'm concerned about right now. What I'm concerned about...(crosstalk)"
- **01:13** – Yevrovich: "Oh my God, the window just burst out."
- Operator: "OK"
- Yevrovich: "Yeah, as fast as they can get here."
- Operator: "We've already got them advised. (crosstalk) Can you pull the fire alarm in the hallway, or can you bang on your neighbor's doors, anything like that? Hello? Hello?"
- **01:34** – End of call

### Fire Scene Examination/Investigation

An on-site field investigation was conducted on January 7-8, 2016 by Ken Rice, Senior Fire Investigator with JENSEN HUGHES. Investigator Rice conducted a second site examination/investigation on January 19-20, 2016 along with JENSEN HUGHES Senior Electrical Engineer Sebastian Scheiff and JENSEN HUGHES Evidence Technician Eric Encell. Various evidence items were recovered from the fire scene during the second site examination. The following pertinent observations were made and recorded during the site examination/investigations; for reference, Figure 2 and Figure 3 are diagrams of Apartment E101 and the southeast bedroom:



Figure 4: Composite image of SE Bedroom, taken 01/08/16, view to southeast.



1. Apartment E101 was extensively fire damaged. The fire patterns confirmed that the fire originated in the southeast bedroom and spread out into the rest of the apartment. The fire breached the south window of the southeast bedroom, spread up the exterior, and entered the attic through the soffit above the third story walkway. The fire spread east and west away from Apartment E101.



**Figure 5: Composite image of SE Bedroom, taken 01/08/16, view to north.**

2. Fire patterns in the southeast bedroom showed that the fire originated on the bed in the southeast quadrant. A fire-damaged wood base of a box spring foundation was found on the floor in this area. The box spring was a few inches away from the east and south walls. The fire damaged mattress and metal box spring frame were found leaning against furniture on the west wall. A view of the southeast bedroom is shown in Figure 4 and Figure 5.



**Figure 6: IMG\_0197, SAS, 01/19/18: SE Bedroom with bed reconstructed. Protected area on mattress shown in yellow and receptacles in red.**

3. The bed in the southeast corner was reconstructed during the examinations, as shown in Figure 6. A protected area of remaining mattress material was found on the top center of the mattress.
4. An unused wood headboard and footboard were leaning against the north wall in front of the closet. A wood, four-shelf dresser and a metal, two drawer file cabinet were located along the center west wall. Both items had fire patterns on them from radiant heat originating from the south and/or east.
5. What appeared to be a short, wood-framed stand or table was found in southwest corner. A relatively large CRT television<sup>5</sup> was on the floor east of the file cabinet along with various device line cords, cables, and other items.
6. The fire patterns in the bedroom, such as the low fire damage patterns on the east wall, along the center of the bed, correlate with the witness statements regarding a fire on the bed spreading up the east wall and breaching the south window.
7. The electrical circuits in the southeast bedroom were traced and documented.
  - a. The bedroom contained one 120V power/lighting circuit. This circuit fed five duplex receptacles (labeled #1-5) in the southeast bedroom and two receptacles in the adjoining southwest bedroom.
  - b. The circuit was wired with older-style NM cables that appeared to be original to the construction of the building. The receptacles were mounted in metal device boxes. No wiring issues or problems were noted.
  - c. The #2 duplex receptacle on the south end of the east wall was removed by the fire department during their site investigation. The laptop computer power supply was plugged into this receptacle.
  - d. There was no ceiling light fixture in the bedroom. Instead, a switch near the doorway controlled a switched outlet in one of the receptacles (most likely receptacle #5, by the door).
  - e. A small table lamp was found along the west half of the south wall. It was plugged into the south wall receptacle (#3). Evidence of electrical arcing was found on the lamp line cord approximately 3-inches from the receptacle.
  - f. A relocatable power tap (RPT) was found plugged into the southwest receptacle (#4). Many electrical devices/items in the southwest corner were plugged into the RPT, including the previously mentioned CRT television, a cable television receiver box, and other unidentified devices.
    - i. The carpet under the TV was unburned.
  - g. The remains of a laptop computer were found leaning against the south wall.
  - h. A 240V electric baseboard heater was mounted at floor level along the south wall.
8. The main circuit breaker (feeder) panel for Apartment E101 was in the northeast corner of the adjoining southwest bedroom.
  - i. The circuit breaker panel was manufactured by Zinsco and appeared to be original to the time of construction.
  - j. The circuit breaker panel sustained limited smoke damage from the fire.
  - k. The 16-slot panel contained 12 circuits, including circuits for the water heater, electric oven range, baseboard heaters, and general power/lighting. Several of the circuit breakers were found in the tripped position.
  - l. One 15A, single-pole circuit breaker protected the southeast bedroom power/light circuit. It was found tripped.
  - m. A 20A, two-pole circuit breaker protected a heating circuit that included the 240V baseboard heater in the southeast bedroom. The circuit breaker was found in the ON position.
  - n. The 125A circuit breaker disconnect in the lower level Utility Room that supplied this panel was found in the ON position

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<sup>5</sup> Cathode ray tube – older television technology using a thick glass vacuum tube.

9. A pile of fire debris was found in the exterior walkway directly outside the southeast bedroom window. The debris was placed outside during the fire-fighting and overhaul activities, and/or the public authority's investigation. The southeast bedroom and debris pile were examined, processed, sifted through, and significant items were recovered as evidence.
  - o. Three Lithium-ion (Li-ion) batteries from the laptop were found.
    - i. One (1) Li-ion cell (Item #53) was found approximately 2-feet west of the bed and 1-foot north of the south wall.
    - ii. One (1) Li-ion cell (Item #53) was found at the center of the head of the bed, approximately 1-foot north of the south wall.
    - iii. One (1) Li-ion cell (Item #3) was found in the debris pile outside the southeast bedroom window.
    - iv. Pieces of copper foil (the remains of the internal jellyroll from a Li-ion battery cell) were found around the bed.
  - p. The bed remains, television, RPT and associated cord and cables, desk lamp remains, and other items were recovered from the fire scene as evidence.
  - q. Debris from the exterior walkway, under the bed in the southeast corner, and other debris from the southeast bedroom were recovered as evidence.
10. No discarded smoking materials, i.e. cigarette butts, were found in the area of fire origin, or in the debris processed from that area. A single cigarette butt was found under the TV that was on the carpeted floor in the southwest quadrant. There was no corresponding, pre-fire, burning or charring of the carpet near the cigarette butt.
11. An unburned, empty package of Complete brand cigarettes was found on the floor near the closet.
12. No ashtrays, butt-cans, etc. were found in the southwest bedroom.
13. A metal can filled with cigarette butts was found outside on the porch.
14. No flammable liquid containers were found in the area of fire origin. One burned, metal, fluid canister was found on top of the dresser on the west wall. A partially burned butane container was found in a drawer of the same dresser.
15. The area surrounding the bed was scanned with the combustible gas detector and no indications of combustible liquid vapors was found.
16. No evidence of e-cigarette or vaping devices, materials, etc. were found in the southeast bedroom. No other Li-ion battery powered devices were found, or known to be located, in the southeast bedroom.

## Research

Laptop: The subject laptop was identified as a Hewlett Packard (HP) laptop, based on information provided by the Home Shopping Network (HSN), who sold the laptop to Mr. Davis. The laptop was purchased on December 5, 2015 and was shipped to Mr. Davis on December 7, 2015. The HSN information and additional research identified the laptop as the following:

1. Make: Hewlett Packard (HP)
2. Model: 15-AC132DS
3. Serial: CND5369NS1
4. Specifications: Intel i3700 Quad Core Processor, 1 GB Ram, 1 TB hard drive, 15-inch LCD monitor
5. Housing Color: Blue
6. Three-cell battery pack
7. 45W AC adapter included

## Laboratory Examinations

The evidence recovered from the fire scene was examined multiple times by multiple parties:



1. August 25, 2016: JENSEN HUGHES Electrical Engineer Sebastian Scheiff and Investigator Rice conducted a join-party laboratory evidence examination of evidence recovered from the fire scene at JENSEN HUGHES' Seattle office, along with representatives of HP.
2. March 20, 2017: JENSEN HUGHES Senior Electrical Engineer Daren Slee, Engineer Scheiff, and Investigator Rice conducted a join-party laboratory evidence examination of the subject HP laptop, Li-ion batteries, power supply, and receptacle at JENSEN HUGHES' Seattle office along with representatives of HP.
3. August 2, 2017: JENSEN HUGHES Engineers Slee and Scheiff, and Investigator Rice conducted a join-party laboratory evidence examination of the subject Li-ion batteries at JENSEN HUGHES' Portland office along with representatives of HP. Based on information and/or an invitation from HP, the presumed manufacturers of the Li-ion battery cells (Samsung) and the battery pack (Simplo) also attended the examination.
4. June 20-21, 2018: JENSEN HUGHES Senior Electrical Engineer Andrew Paris conducted a nondestructive examination of selected evidence items at JENSEN HUGHES' Seattle office.

The following pertinent observations were made and recorded during the various evidence examinations:

1. Exemplar Laptops: Exemplar refurbished HP laptops were purchased for comparison purposes (Figure 7).



**Figure 7: Exemplar HP laptop.**

- a. The laptops came with three-cell Li-ion battery packs (Figure 8 and Figure 9) with the following specifications:
  - i. HS03 Rechargeable Battery
  - ii. HP Part Number: 807611-141 or 807956-001
  - iii. Serial Numbers: 6EZRP04WY8VLD0 and 6EZRP04WY8W0HF
  - iv. Specifications: 11.1V, 31Wh, 2620mAh



**Figure 8: IMG\_0039, SAS, 10/31/16: Battery pack from exemplar HP laptop.**



**Figure 9: X-Ray image of exemplar battery pack showing the three internal Li-ion battery cells.**

2. Item #42: Laptop recovered from the southeast bedroom
- The laptop was heavily fire damaged. Much of the exterior plastic housing was burned and/or melted away. The top and under sides of the laptop are shown in Figure 10 and Figure 11.
  - The laptop was x-rayed, and the image showed that the internal circuit boards and components were mostly intact (Figure 13). There were no specific, localized areas of internal damage to the motherboard, hard drive or keyboard.
  - The battery pack area was the most significantly damaged portion of the laptop. The battery pack was still inserted into the laptop charging terminals. The top cap for one of the three Li-ion battery cells was still attached to the battery pack / laptop remains (Figure 12).



**Figure 10: IMG\_0023, SAS, 08/25/16: Top side of laptop. Location of battery pack (red) and Li-ion cell cap (yellow) indicated.**



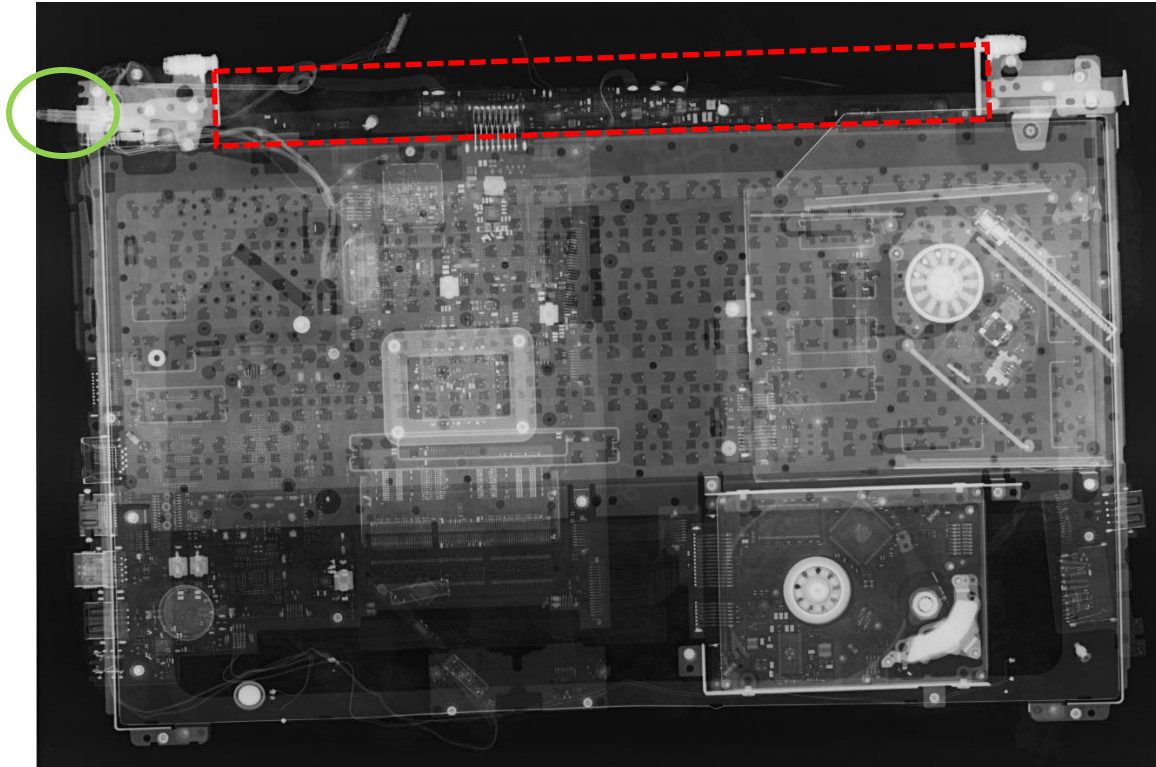


**Figure 11: IMG\_0016, SAS, 08/25/16: Underside of laptop. Location of battery pack indicated (red).**



**Figure 12: IMG\_03012, SAS, 08/25/16: Li-ion battery cell top cap attached to laptop.**

- d. The DC power plug, separated from the power cord, was found inserted into the laptop at the left rear corner (Figure 13 and Figure 14). This showed that the laptop was plugged in and energized at the time of the fire.



**Figure 13: X-ray of subject laptop. Battery pack indicated in red, and charging port with DC plug inserted in green.**



**Figure 14: IMG\_0023, SAS, 08/25/16: Laptop with DC plug inserted into the charging port.**

- e. The battery management unit (BMU), i.e. the control board within the battery pack, was removed from its connection to the laptop (Figure 15).
- i. The charging terminals were not melted or locally heated.



- ii. A secondary fuse protection device on the BMU was found melted open. This fuse cuts off charging current to the battery pack. This fuse could melt due to external heat or from an overcharge / voltage differential event.
- iii. The Charging FET<sup>6</sup> (CFET) and Discharging FET (DFET) control the charging and discharging current to and from the battery pack. The FETs were electrically measured, and they were functional.
- iv. The current sense resistor measures charging and/or discharging current. This resistor was electrically closed (i.e. intact, not open).
- v. Other components on the BMU were damaged in the fire and could not be measured.
- vi. There was an intention during the examination to try and collect memory data from the BMU control chip, but the tools likely need were proprietary to the apparent manufacturer of the battery pack, Simplo. However, Simplo did not have the required equipment during the examination and the data download could not be done.



**Figure 15: IMG\_0177, DTS, 03/20/17: Subject BMU with top cap of cell still attached (red).**

- 3. Items 3 & 53: Three Li-ion battery cells
  - a. Two of the battery cells were recovered from the southeast bedroom (Item #53), and one from the exterior walkway outside the south window (Item #3).

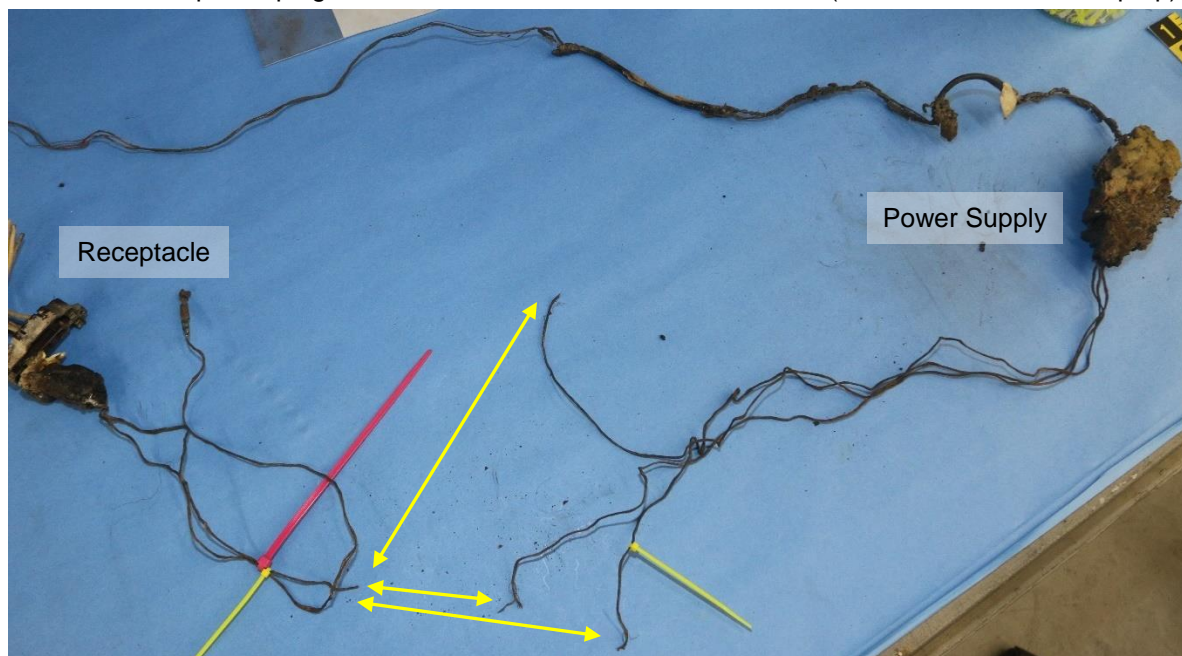


**Figure 16: IMG\_0143, DTS, 03/20/17: Subject Li-ion cells placed back in their original configuration.**

<sup>6</sup> Field Effect Transistor – a type of semi-conducting electronic switch.

- b. All three battery cells were consistent with the style and dimensions of an 18650-sized Li-ion cell. They all contained three, similarly-sized vent holes in the cell cap. These size/type of cells were consistent with those that would have been in the HP battery pack.
  - c. HP identified the manufacturer of the cells as Samsung.
  - d. All three battery cells were fire-damaged and corroded. The steel cans were corroded and had irregular shaped holes that penetrated the can wall. They had all vented their electrolyte.
  - e. The cap was missing from one of the cells (Item #3, found outside) and the internal jellyroll was expelled when the cell explosively vented. The top cap matching this cell was found attached to the laptop battery pack / laptop remains. The other two cells still had the top caps attached.
  - f. Based on their characteristics and their configuration in the pack, the cells were identified as:
    - i. V-positive ( $V_p$ ) – Item #3 – Weight: 7.6g – Length: 68.1mm
    - ii. V-middle ( $V_m$ ) – Item #53 (Sample 1) – Weight: 34.6g – Length: 64.8mm
    - iii. V-low ( $V_L$ ) – Item #53 (Sample 2) – Weight: 33.5g – Length: 66.6mm – Long connector strap connected to negative end.
  - g. The cells were x-rayed and scanned with Computed Tomography (aka CT scan).
  - h. Attempts were made to remove the top cap from the Item #53, Samples 1 and 2 cells. However, the cans were severely corroded and degraded and they came apart during the process. The jellyrolls were removed, and attempts were made to unroll them, however they were too fragile and began to crumble apart.
4. Item #1: Receptacle (#2) and laptop power supply
- a. The fire department removed this item from the fire scene and later transferred it to JENSEN HUGHES.
  - b. The 120V duplex receptacle was originally located in the east wall next to / behind the bed on the floor in the southeast corner.
    - i. The receptacle face was damaged from an external fire and the plastic housing was partially burned/melted. The branch circuit conductors were not fire damaged.
    - ii. There was no evidence of localized heating or melting on the internal bus bars or push-in branch circuit connections.
  - c. The laptop power supply converted the incoming, 120V AC power into DC power to supply the laptop.
    - i. The plastic housing was fire damaged and partially charred and/or melted away.
    - ii. The remains of carpet and/or padding were found on the power supply housing, indicating it was on the carpeted floor during the fire, most likely on the east wall next to the bed.
    - iii. The power supply housing was opened to expose the internal circuitry and components. The internal components appeared to be intact and relatively undamaged. There was no evidence of pre-fire physical damage, corrosion, etc.
  - d. A three-conductor, stranded copper, AC line cord was attached to the power supply. The line cord plugged into the receptacle through a polarized grounding adapter that converted the three-blade line cord plug into a two-blade plug.
    - i. The grounding adapter, AC line cord, and receptacle connection(s) was disassembled and no evidence of localized heating, melting, or electrical arcing was found.
    - ii. The line cord was fire damaged and much of the insulation was burned away. The line cord was severed approximately 11.5-inches from the receptacle. The severed ends showed evidence of melting and beading indicative of electrical arcing.
    - iii. No additional arcing was found on the remaining 25-inches of line cord.
  - e. A three conductor, stranded copper DC cord extended out of the power supply. Much of the cable jacket and conductor insulation was burned and/or melted away.
    - i. The DC cord remains measured approximately 70-inches.

- ii. No melting was found on the DC power cord conductors.
- iii. The DC power plug was not found attached to the conductors (it was attached to the laptop).



**Figure 17: IMG\_0035, SAS, 03/20/16: Laptop power supply, receptacle, and arc-severed line cord.**

5. Item 39: Receptacle with various plugged in.
  - a. The RPT and associated items were originally located in the southwest corner of the room.
  - b. A large, older-style, CRT television was found in this area. The plastic television housing was burned and melted top-down. The main circuit board at the base of the TV was relatively undamaged and there was no evidence of a localized failure. The carpet under the TV was unburned.
  - c. A Comcast converter/receiver box was found to have been on floor of the bedroom. The modem was burned top-down from an external fire and here was no evidence of an internal fire/failure.
  - d. The RPT was fire damaged in a top-down manner from an external fire.
    - i. Six items were plugged into the RPT. There was no evidence of localized heating, melting, or failure at the RPT outlet / line cord connections.
    - ii. No evidence of electrical arcing was found on the associated line cords.
6. Item 50: Receptacle #3 and desk lamp.
  - a. The 120V duplex receptacle was damaged from an external fire. There was no evidence of localized heating, melting or failure to the receptacle components.
  - b. The metal desk lamp contained a two-conductor line cord. The conductor insulation was melted/burned away. The line cord conductors were severed by an arcing event approximately 2-inches from the plug end. The plug blades showed no evidence of localized heating, melting, or arcing.
7. Item #36: Electric baseboard heater from Unit E101.
  - a. The aluminum radiator fins were all intact. There was no evidence of a localized heat/melt pattern on the radiator fins.
  - b. There were no breaches in the heating element.
  - c. The internal and branch circuit wiring were intact on the right (west) side of the heater. The internal wiring on the left side of the heater was charred. No evidence of electrical arcing was found on the wiring or internal components.



8. Item 46: Receptacle #4
  - a. A small AC/DC power supply was found plugged into this receptacle, such as that used for a cell phone, or other small DC-powered device.
  - b. The power supply was external heat/fire damaged. The internal components were intact and mostly undamaged. There was no evidence of an internal failure.
9. Additional items and debris pertinent to the fire origin and cause investigation were examined and/or sifted through.
  - a. No additional components of the laptop were found in the remains of the mattress.
  - b. No additional electrical components were found when the collected debris was sifted.
  - c. No evidence of an internal failure was found on the other receptacles recovered from the southeast bedroom.
  - d. The branch circuit wiring supplying the receptacles was not damaged by fire.

## ANALYSIS/DISCUSSION

### Origin Determination

The witness statements, fire pattern analysis, electrical arcing analysis, and the results of the evidence examinations showed that the fire originated on the bed in the southeast quadrant of the southeast bedroom.

1. NFPA 921 states in Section 18.12 that four main factors are used to determine the origin of a fire:
  - a. Witness Information and/or Electronic Data
  - b. Fire Patterns
  - c. Fire Dynamics
  - d. Arc mapping
2. Witness Statements:
  - a. The surviving eyewitness, Ms. Yevrovich, was interviewed several times soon after the fire by various parties from the public and private sectors, including JENSEN HUGHES. Ms. Yevrovich was also the original 911 caller, and her statements and the background noises on the call provided additional information.
  - b. The statements and initial comments made by Ms. Yevrovich differ in detail and leave a certain amount of confusion as to what exactly happened on the evening of the fire, due to her contradictory and incorrect statements. However, she was consistent in multiple aspects of her firsthand, eye-witness accounts of witnessing the fire. These statements correlate with the 911 call information and the fire origin and cause investigation. These aspects include:
    - i. She smelled an unusual smoke smell and she jumped up to investigate.
    - ii. She opened the door to the southeast bedroom and saw Mr. Davis standing away from the bed, near the center of the room.
    - iii. Mr. Davis was clothed, wearing a down coat, and he was not on fire.
    - iv. There was a fire on the mattress.
    - v. The fire spread up the wall.
3. Fire Patterns:
  - a. The fire patterns in the southeast bedroom showed that the heaviest fire damage occurred in the southeast quadrant. The box spring and mattress in the southeast quadrant were heavily fire damaged. The burn patterns on the front of the west wall dresser and unused wood bedframe on

the north wall showed evidence of radiant heat/fire patterns coming from the south and/or east. The bedroom door was left open and it was burned from the south. In all, the fire patterns in the room correlate with the eyewitness statements that the fire originated on the bed.

- b. The bed and box spring were fire damaged and charred down to floor level. There was low charring on the baseboard trim on the east wall, along the center of the length of the bed. However, the baseboard trim was protected and unburned where it faced the ends of the bed. One would expect the baseboard trim to have been uniformly protected had the fire originated elsewhere in the room and the bed was attacked by uniform radiant heat, and it ignited and burned.

#### 4. Fire Dynamics:

- a. The innerspring mattress located in the area of fire origin is a combustible item that is a competent first fuel for a fire. Innerspring mattresses are made of a fabric cover, upholstery layers, and an insulator pad or netting.<sup>7</sup> The upholstery layers are typically made of natural and synthetic materials, such as polyurethane foam, latex foam, polyester fibers, etc.<sup>8</sup> The fabric cover is very often made from polyester fabrics, especially on lower cost models.<sup>9</sup> Polyester fabrics have an ignition temperature of 800°F to 1,000°F,<sup>10, 11</sup> and polyurethane foams ignite around 780°F.<sup>12</sup>
- b. A competent ignition source was located in the area of fire origin at the time of the fire, namely the laptop computer. Li-ion batteries in thermal runaway can reach temperatures between 1,200°F and 1,650°F,<sup>13</sup> and they can shoot out highly flammable gases that often ignite,<sup>14</sup> producing a torch-like flame.<sup>15</sup> Cigarette smoking was also considered as a possible ignition source, as detailed in the Fire Cause Analysis section below.

#### 5. Arc Mapping

- a. Arc-mapping is a well-known technique in the fire investigation field, as referenced in NFPA 921.<sup>16</sup> Electrical arc mapping involves surveying electrical conductors and equipment in a fire-damaged area, identifying electrical arcing events, and using the location of those events to help determine the area of fire origin.
- b. Electrical arcing events often occur in a fire when the fire attacks and damages the cable/conductor insulation, which allows the conductors to contact each other and electrically arc.
- c. Often an arcing event will trip an overcurrent protective device (OCPD) such as a circuit breaker or fuse. In some cases, the arcing event may completely sever the conductor(s). If the initial arcing event doesn't trip the OCPD or sever the circuit, the circuit will remain energized and it could then arc at another location. Based on this general principle, the furthest downstream arcing event (i.e. away from the source of power) would have been damaged/attacked by fire first.

<sup>7</sup> [http://mattresses101guide.com/Mattress\\_Construction\\_Mattress\\_Upholstery\\_and\\_foam\\_beds.html](http://mattresses101guide.com/Mattress_Construction_Mattress_Upholstery_and_foam_beds.html)

<sup>8</sup> Mattress, How Products Are Made, <http://www.madehow.com/Volume-1/Mattress.html>

<sup>9</sup> Nells, Barbara, All dressed up: Mattress fabrics play many roles, *Bed Times*, 1 Nov 2009, <https://bedtimesmagazine.com/2009/11/dress-up/>

<sup>10</sup> Flammability of Fibers, *Alpha Engineered Products*, <http://www.fairprene.com/flammability.htm>

<sup>11</sup> Physical Constraints For Investigators, *T.C. Forensic*, <http://www.tcforsic.com.au/docs/article10.html>

<sup>12</sup> Q&A on Fire and Fire Prevention of Rigid Polyurethane Foam, *Japan Urethane Industry Institute*, May 2009.

<sup>13</sup> Golubkhov, Andrey, et al, Thermal-runaway experiments on consumer Li-ion batteries with metal-oxide and olvin-type cathodes, *Royal Society of Chemistry*, 27 Nov 2013.

<sup>14</sup> Golubkhov, Andrey, et al.

<sup>15</sup> Kahn, Michael, et al.

<sup>16</sup> NFPA 921, 2017 Ed., Article 18.4.5.



- d. In this case, electrical arcing events were found on the laptop charger AC line cord in the southeast corner, and on the desk lamp line cord on the south wall. Correspondingly, the circuit breaker for the single power circuit in the southeast bedroom was tripped.
  - e. No arcing was found on other exposed and/or fire damaged conductors in the bedroom. The branch circuit wiring in the walls sustained minimal to no damage, as the fire did not penetrate the walls where the circuit conductors traveled.
  - f. The arcing on the laptop power supply AC line cord was the furthest downstream arcing found in the room of fire origin, based on the routing of the circuit. This arc mapping evidence correlates with the witness statements and burn patterns that showed the fire originated on the bed in the southeast quadrant.
6. The origin determination factors referenced in NFPA 921 support a fire originating on the bed in the southeast corner of the southeast bedroom.

### Fire Cause Analysis

1. The fire that occurred on the evening of December 31, 2015 took the life of a middle-aged, ambulatory man. Mr. Davis was reportedly a cigarette smoker and heavy drinker, and these factors were evaluated during the course of our investigation and analysis.
2. There was nowhere else to sit up or lay down in the southeast bedroom other than the bed in the southeast corner. It is therefore likely Mr. Davis was on the bed while he was in the room prior to the fire. That was also the location he most likely would have used the laptop, which correlates with Ms. Yevrovich's statement that the laptop was always on the bed.<sup>17</sup>
3. Ms. Yevrovich stated that Mr. Davis had prior incidents with drinking and falling asleep or passing out while smoking, however none of these ever resulted in any reported fires or injuries.
4. Ms. Yevrovich stated that Mr. Davis' bed consisted of a mattress and box spring laid on the floor. She stated that there were no linens/sheets on the bed, most likely because Mr. Davis often soiled the bed.<sup>18</sup> Although she said there may have been blanket, she did not witness anything on the bed at the time of the fire.<sup>19</sup> This comports with Ms. Yevrovich's statements that Mr. Davis was clothed and wearing a down-filled coat at the time of the fire and would therefore have not needed a blanket.
5. The fire was already in flaming combustion when she first witnessed the fire. She stated several times that she was alerted to the fire when she smelled smoke and ran into the southeast bedroom to find a fire on the bed.
6. Multiple ignition scenarios were considered during our investigation.
  - a. Mr. Davis intentionally ignited his mattress with an open flame.
    - i. Mr. Davis had no reported history or allegations of intentionally igniting a fire before.<sup>20</sup> He had no reported suicidal tendencies, nor history of causing property damage.<sup>21</sup> He and Ms. Yevrovich had fought in the past and she did not report previous property damage or violence against her. There is no reasoning or rationale that would explain this type of behavior by Mr. Davis.

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<sup>17</sup> EPD/EFD Recorded Interview with Lynn Yevrovich, 6 Jan 2016.

<sup>18</sup> EPD/EFD Recorded Interview with Lynn Yevrovich, 6 Jan 2016.

<sup>19</sup> EPD/EFD Recorded Interview with Lynn Yevrovich, 6 Jan 2016.

<sup>20</sup> EPD/EFD Recorded Interview with Lynn Yevrovich, 6 Jan 2016.

<sup>21</sup> EPD/EFD Recorded Interview with Lynn Yevrovich, 6 Jan 2016.

- b. Mr. Davis fell asleep or passed out while smoking in bed.
- i. No used smoking materials (i.e. cigarette butts) were found within in the area of fire origin, or in the debris from the area of fire origin that was processed during the investigation. Other than one old cigarette butt under the TV and an empty pack of cigarettes near the closet, there was no evidence of active, long term smoking in the bedroom, i.e. there were no ashtrays, butt cans, distributed cigarette butts, etc. found in bedroom.
  - ii. Mr. Davis did not have a history of igniting fires while smoking in the past.
  - iii. Although Mr. Davis was reportedly known to pass out drunk, he would apparently do so while curled up on the bed, according to Ms. Yevrovich.<sup>22</sup> However, in this case, Mr. Davis was not on fire, nor injured when the fire was discovered. He was clothed, conscious, communicative, ambulatory and he was positioned away from the mattress when the fire was discovered, and in the moments thereafter.
  - iv. Assuming Mr. Davis passed out or fall asleep with a lit cigarette, and that the cigarette then ignited surrounding combustible items (this is not guaranteed, for reasons stated below), it still does not explain how the fire did not ignite his clothes, especially the likely flammable down-filled coat he was wearing at the time of the fire. If he was sleepy or drunk enough the ignite surrounding combustibles, one would expect that he would continue in that state until he overcome by smoke and didn't wake up, or he was burned, and his clothes were ignited. Neither of these possibilities occurred and instead Mr. Davis was conscious, unburned, and standing away from the fire.
  - v. Recent research has shown that although smoking in a bedroom is a known hazard and cause of fires, fatal victims of smoking-material fires are often sleeping (39%) or attempting to escape, fight the fire or rescue someone or something (36%), for a total of 75% of fatalities, with alcohol use compounding the problem (19%).<sup>23</sup> In this case Mr. Davis was not sleeping, nor burned, when the fire was discovered, which tends to indicate he suddenly became aware of the fire, and he may have been stunned and/or figuring out what to do.
  - vi. Additionally, the reports by Ms. Yevrovich of smelling smoke and then running into the bedroom and finding a developed fire on the bed comport with a relatively fast ignition/moving fire, not a slow, smoldering fire.
    1. For one, the smoke detector, which can be heard sounding off in the 911 call, did not alert Ms. Yevrovich of the fire, rather she smelled the smoke first. A slow smoldering fire produces smoke for an extended period due to its longer duration, and therefore the smoke detector would have been more likely to sound off earlier. Smoke detectors are very valuable in detecting smoldering fires from cigarettes.<sup>24</sup>
    2. Even if it didn't, Ms. Yevrovich still quickly noticed a strange smell and ran to investigate. She entered the room and found a developed fire on bed and the room was not too smoky to see.
    3. Additionally, she was speaking coherently and not coughing in the 911 call, indicating that the smoke was not initially that heavy, even though the fire was developed, another sign of fast-developing fire, not a slow smoldering fire.

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<sup>22</sup> EPD/EFD Recorded Interview with Lynn Yevrovich, 6 Jan 2016.

<sup>23</sup> Hall, John Jr., *The Smoking-Material Fire Problem*, National Fire Protection Association, July 2013.

<sup>24</sup> *Smoking-Related Fires in Residential Buildings (2008-2010)*, TFRS Vol. 13, Issue 6, FEMA, June 2012.

4. Although Mr. Davis' state of mind is unclear, he was conscious and communicative at the time of the fire. However, he apparently did not warn Ms. Yevrovich, indicating he may have been shocked/confused by a suddenly igniting fire.
- vii. While cigarettes can ignite fires, they are not ready ignition sources for all combustible items. The fact that there is no open flame on the end of a cigarette, and its relatively small thermal mass, somewhat limits the types of fuels that it will readily ignite. For instance, while a cigarette will readily ignite crumpled-up paper, tissues, light plastics, etc. in a trash can, it is harder for a cigarette to ignite a combustible item with more mass, like a mattress, solid wood, etc., as compared to an open flame.
- viii. Mr. Davis reportedly smoked Camel Wide Blue cigarettes, although there was also an empty package of Complete brand cigarettes found in the bedroom. In any case, all cigarettes sold in Washington state at the time of the fire were required to comply with the standards for Fire Standard Compliant (FSC) cigarettes. As of 2011 all 50 states have enforced model legislation mandating the sale of fire-safe cigarettes,<sup>25</sup> including Washington state in 2009.<sup>26</sup>
- ix. These standards require that cigarettes contain safety provisions that cause them to go out if they are unattended, i.e. a person is not regularly inhaling them.<sup>27</sup> This decreases the time that the burning cigarette end stays lit and decreases the amount of time that it could be a potential ignition source. The purpose of the fire-safe cigarette design is to decrease the propensity of the smoldering cigarette to ignite mattresses, bedding and upholstered furniture.<sup>28</sup> This change in cigarettes and changes in mattress and furniture construction have led to a long-term decline in cigarette-caused fires.<sup>29</sup>
- x. FSC cigarettes are tested to ASTM E 2187, Standard Method for Measuring the Ignition Strength of Cigarettes. In the test, a lit cigarette is placed on a substrate made of a stack of very thin paper. If the cigarette burns strongly, it will continue burning despite this heat loss, potentially being capable of igniting a real bed of piece of upholstered furniture.<sup>30</sup> This process is repeated 40 times, with pass rate of <10 cigarettes that burn their full length. This means that new cigarettes do not burn as long as the pre-regulation cigarettes.<sup>31</sup>
- xi. Mr. Yevrovich noted that there weren't sheets on the mattress. She said there may have been a blanket on the bed, but she also didn't note anything on the bed when she first observed the fire.<sup>32</sup>
- xii. Mattresses are difficult to ignite with a smoldering cigarette due to long-standing federal regulations on the flammability of mattresses. 16 CFR Part 1632, Standard For The Flammability of Mattresses and Mattress Pads, was introduced in 1973 and was designed to prevent and/or limit the ignition of mattresses from smoldering cigarettes. The standard provides a test to determine the ignition

<sup>25</sup> History of Fire-Safe Cigarettes, National Fire Protection Association, <https://www.nfpa.org/Public-Education/By-topic/Top-causes-of-fire/Smoking/Coalition-for-Fire-Safe-Cigarettes/History>, 2018.

<sup>26</sup> States that have passed fire-safe cigarette laws, National Fire Protection Association, <https://www.nfpa.org/Public-Education/By-topic/Top-causes-of-fire/Smoking/Coalition-for-Fire-Safe-Cigarettes/States-that-have-passed-fire-safe-cigarette-laws>, 2018.

<sup>27</sup> About fire safe cigarettes, National Fire Protection Association, <https://www.nfpa.org/Public-Education/By-topic/Top-causes-of-fire/Smoking/Coalition-for-Fire-Safe-Cigarettes/About-fire-safe-cigarettes>, 2018.

<sup>28</sup> Frequently asked questions, National Fire Protection Association, <https://www.nfpa.org/Public-Education/By-topic/Top-causes-of-fire/Smoking/Coalition-for-Fire-Safe-Cigarettes/Frequently-asked-questions>, 2018.

<sup>29</sup> Myths versus realities, National Fire Protection Association, <https://www.nfpa.org/Public-Education/By-topic/Top-causes-of-fire/Smoking/Coalition-for-Fire-Safe-Cigarettes/Myths-versus-realities>, 2018.

<sup>30</sup> Myths versus realities, NFPA.

<sup>31</sup> Myths versus realities, NFPA.

<sup>32</sup> EPD/EFD Recorded Interview with Lynn Yevrovich, 6 Jan 2016.

resistance of a mattress or mattress pads, when exposed to lighted cigarette. This standard does not cover the ignition of mattress from open flame.

- xiii. CFR Part 1632 requires pre-market prototype testing for each new mattress design. In addition, prototype testing must be performed when there has been a change in materials of an existing prototype design that could influence the cigarette ignition resistance.
  - xiv. Six mattress surfaces must be tested for each prototype. Tests mandated by the standard measure the ignition resistance by exposing surfaces to a lighted cigarette. The open top, taped edges, and quilted or tufted areas are tested by placing a lit cigarette on that area. The standard also requires a 2-sheet test where a lit cigarette is placed between the sheets and the mattress. The tests expose each surface to a minimum of 18 lighted cigarettes – at least nine on the bare mattress side and at least nine on the two-sheet side. The prototype is accepted if the char length of each individual cigarette location on all six mattress surfaces is not more than two inches in any direction from the nearest point of the cigarette.<sup>33</sup>
  - xv. The area tested passes if the cigarette does not leave a char length over 2 inches. If the cigarette creates a flame before the char reaches 2 inches, the test should immediately be recorded as a failure.<sup>34</sup>
  - xvi. A related standard, federal law 16 CFR 1633 covers the ignition of mattress from an open flame. This standard came into effect in 2007. Based on Ms. Yevrovich's descriptions of the mattress as being an old twin mattress, the conditions that Mr. Davis and Ms. Yervovich lived in, and the amount of time they lived together (five years, with previous years together as a couple) with no reports of a new bed in Mr. Davis' room, it is unlikely that the mattress in the southeast bedroom was newer than a 2007 model.
  - xvii. The evidence shows that it is less likely that Mr. Davis was smoking a cigarette and ignited the mattress in this case.
- c. A failure of the subject HP laptop ignited the fire.
- i. Li-ion batteries are used in numerous applications due to their higher power efficiency and density compared to older forms of battery technologies, such as lead-acid and nickel-cadmium.<sup>35</sup> Li-ion battery cells are found in products ranging from flashlights, to computers, to electric vehicles, etc.
  - ii. Li-ion battery cells are constructed of anode (-) and cathode (+) electrode layers sandwiched between a separator layer (a thin sheet of perforated plastic), as shown in Figure 18. The anode layer is typically made of copper coated with graphite, while the cathode layer is made of aluminum coated with a metal oxide (traditionally lithium cobalt oxide, but other materials are also available).<sup>36</sup> The anode and cathode layers are rolled up in order to increase the total surface area, and thus electrical charge, of the resulting cell. The rolled-up electrode layers are known in the industry as a jellyroll.<sup>37</sup>
  - iii. The anode/cathode jellyroll is then inserted into a cylindrical steel housing. The cell is filled with an electrolyte, typically an organic solvent, such as ether, combined with a dissolved lithium salt.

<sup>33</sup> 16 CFR 1632 – Standard for the Flammability of Mattresses and Mattress Pads.

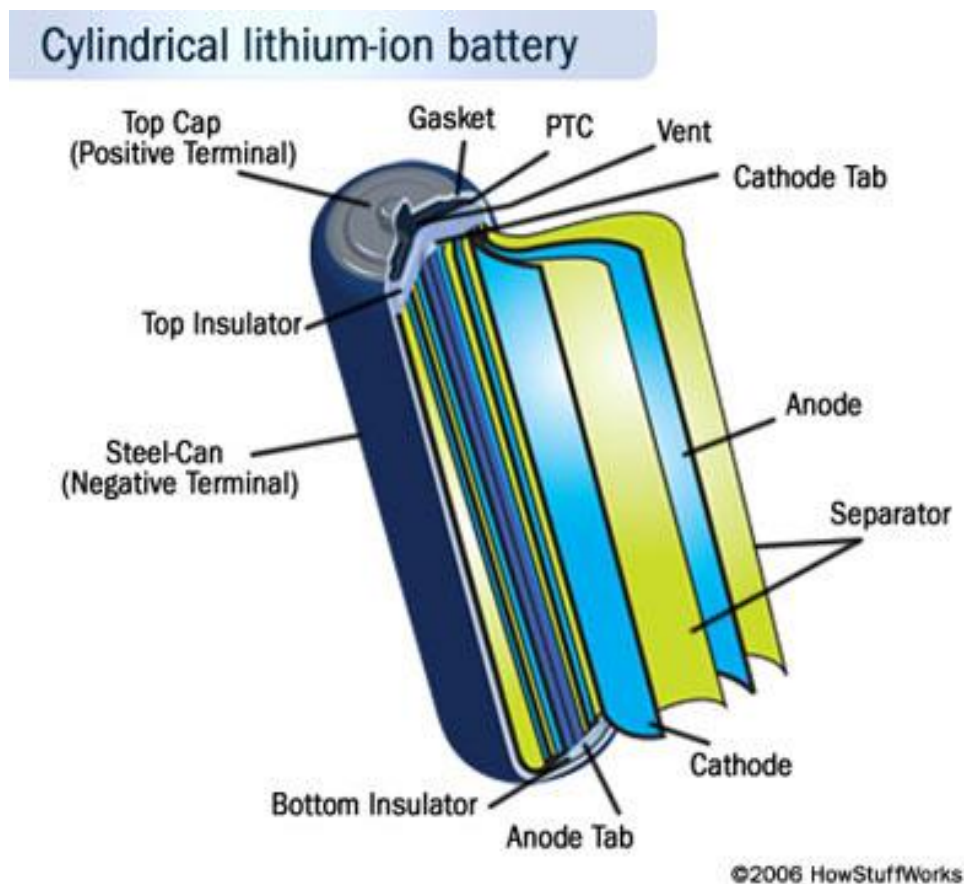
<sup>34</sup> 16 CFR 1632 – Standard for the Flammability of Mattresses and Mattress Pads.

<sup>35</sup> Mekonnen, et al., A Review of Cathode and Anode Materials for Lithium-Ion Batteries, *SoutheastCon 2016*, April 2016.

<sup>36</sup> Mekonnen, et al.

<sup>37</sup> Kahn, Michael, et al.

- iv. During charging, lithium ions move from the cathode to the anode through the electrolyte. A voltage potential is created between the now oppositely charged anode and cathode. When discharging, the reverse operation occurs, and electrical current is supplied to the attached load.



**Figure 18: Diagram of cylindrical Li-ion battery cell.**

- v. The subject HP laptop was plugged in and energized the area of fire origin at the time of the fire. The laptop contained electrical components, including three Li-ion battery cells, that can fail and ignite a fire. All three of the Li-ion cells vented during the event, indicating they reached an internal temperature over 1,000°F.<sup>38</sup> Failed Li-ion cells are a competent ignition source according to many sources.<sup>39,40,41,42</sup>
- vi. A simple Internet search will reveal a multitude of incidents where Li-ion batteries have failed and caused a fire. JENSEN HUGHES has also investigated multiple fires where Li-ion batteries were shown to be the cause of a fire, including several related to laptop battery packs. The subject laptop battery pack was a competent ignition source in the area of fire origin and therefore cannot be eliminated as a cause of the fire.
- vii. In general, a Li-ion cell can fail in three basic ways: from external mechanical or heat damage, electrical stress (overcharging, shorting, etc.), or from an internal defect. In each of these cases, the

<sup>38</sup> Kahn, Michael, et al.

<sup>39</sup> Kahn, Michael, et al.

<sup>40</sup> BU-304a: Safety Concerns with Li-ion. *Batteryuniversity.com*, accessed 08 March 2016.

<sup>41</sup> Why lithium batteries keep catching fire. *The Economist*, 27 Jan 2014.

<sup>42</sup> Wang, et al., Thermal runaway caused fire and explosion of lithium ion battery. *Journal of Power Sources*, 13 Feb 2012.



most damaging result is breakdown and/or bridging of the cell separator, which allows the electrode layers to directly short. This can quickly discharge the battery internally. The cell typically reacts by overheating very quickly.

- viii. During an internal cell failure, the cell separator can break down, allowing the anode and cathode layers to directly short and dissipate the battery charge internally. The amount of heat released in this event is very significant, with the internal cell temperature reaching up to 1220°F in a short amount of time.<sup>43</sup> This can cause the internal liquid/gel electrolyte to boil off. The resultant gases can pressurize and vent from the cell housing through the top cap.
- ix. Li-ion cells typically contain a venting mechanism that is supposed to allow the resultant gases to escape while keeping the cell mechanically intact. This mechanism is supposed to operate when the cell heats up gradually, whether due to external heat (abnormally high ambient air temperatures, fire, etc.), an overcurrent draw, or overcharging.<sup>44</sup>
- x. However, the venting mechanism doesn't always work correctly, especially if the cell shorts internally and the cell temperatures rise quickly. In those cases, the gases can cause a sudden shift of the jellyroll that in turn blocks the venting mechanism at the top cap of the can housing. Once that occurs, and if the pressure continues to build, the steel can may deform. This can be seen in the subject Li-ion cell with the blown top cap (Item #3), where the flat bottom of the cell bulged outwards.
- xi. In extreme cases, the pressure can be intense enough to blow the end cap off the cell and eject the cell contents.<sup>45</sup> This is what occurred in one of the Li-ion cells (Item #3) from the subject laptop. The electrolyte in a Li-ion cell is typically flammable. Sparks or hot particles can ignite the venting electrolyte liquid/vapor/gas.<sup>46</sup> The ejected flaming electrolyte and hot metal pieces/particles of the jellyroll can ignite a fire if they contact combustible items. As shown during our investigation, pieces/particles of the copper jellyroll were thrown in all directions.
- xii. The resulting fire and/or the extreme temperature rise of a failed cell can cause other cells in the pack to also overheat and explosively vent. Additionally, the heat from the cell (>1,200°F) and/or venting electrolyte can melt surrounding plastic materials, such as the plastic housing of the battery pack and the laptop housing.
- xiii. A search of the United States Consumer Products Safety Commission (CPSC) shows that over the past 15 years most major computer manufacturers have issued recalls for Li-ion batteries due to defects that led to fires. This includes recalls by HP in 2018, 2017, 2016, 2013, 2011, 2010, 2009, 2008, 2006, and 2005. There are also many reports from consumer regarding failed HP Li-ion battery packs on the CPSC website.<sup>47</sup> This shows that Li-ion batteries can fail and cause fires.
- xiv. Internet searches of laptop battery failures and/or fires show images and videos of laptop batteries melting/venting through a laptop housing.<sup>48, 49, 50, 51</sup> JENSEN HUGHES has investigated multiple fires where the battery cells melted through the plastic battery pack and laptop housing before igniting a

<sup>43</sup> Kahn, Michael, et al.

<sup>44</sup> Kahn, Michael, et al.

<sup>45</sup> Kahn, Michael, et al.

<sup>46</sup> Kahn, Michael, et al.

<sup>47</sup> <http://www.saferproducts.gov>

<sup>48</sup> <http://blogs.smh.com.au/mashup/archives/005359.html>

<sup>49</sup> <https://www.youtube.com/watch?v=mlZggVrF9VI>

<sup>50</sup> <https://bgr.com/2018/03/26/laptop-battery-fire-recall/>

<sup>51</sup> <http://www.deadlinenews.co.uk/2017/06/01/pics-shows-devastation-caused-exploding-laptop-batteries-bought-cheap-ebay/>

larger fire. Our experience along with Internet research shows that laptop failures igniting beds are known to occur.<sup>52, 53</sup>

- xv. Li-ion cells are a competent ignition source and capable of igniting a mattress and/or bedding. As previously mentioned, the cell temperatures can reach over 1,200°F during an internal failure, and when they vent the ignited gases can produce a torch-like effect<sup>54</sup> that can ignite surrounding combustible items from the open flame and ejected molten particles. Additionally, the ignition of the plastic housing of the laptop can lead to the ignition of surrounding combustible items such as a mattress and/or bedding.
- xvi. As mentioned above, a Li-ion battery cell can fail internally, due to a manufacturing defect. This can occur for several reasons, including, but not limited to:<sup>55</sup>
  - 1. Migration of metal particles inherent in the electrolyte, or introduced by the manufacturing process, that in turn can bridge the separator and cause the electrolytes to short.
  - 2. Electrode or separator damage leading to electrode shorting.
  - 3. Secondary failures of the internal protective devices, such as the PTC disconnect or the vent tube, that don't allow built up internal gases to stop generating and/or escape in a safe manner.
  - 4. Defects in the cell anode that can cause a buildup of lithium dendrites that can cause resistive heating inside the cell, lead to cell shorting, and thermal runaway.
- xvii. A Li-ion battery can also fail due to electrical stresses, such as from:
  - 1. Overcharging, where the cell voltage is increased significantly above the nominal 3.7-4.2V. This can lead to exothermic degradation of the electrodes and separator, and result in a thermal runaway event.<sup>56</sup>
  - 2. External short circuit, such as a direct short across the + and – battery terminals.<sup>57</sup>
  - 3. Over-discharge, i.e. discharging the battery voltage significantly below the nominal cell voltage (in this case 3.7V). This can damage the internal electrodes and cause thermal runaway.<sup>58</sup>
- xviii. To combat cell failure battery packs typically contain protection circuitry (BMU) that will shut off the charging current, or disconnect the cells from the load, in order to prevent a catastrophic failure. The protection circuitry typically works to detect instances of overcharging, overcurrent draw, overtemperature, as well as checking to make sure all the cells in a multiple-cell pack are operating at the appropriate voltage and capacity.<sup>59</sup>
  - 1. Battery pack control circuitry failures do occur and can lead to a multitude of battery cell failure, such as those mentioned above.<sup>60</sup> Possible PCB failures include capacitors,

<sup>52</sup> <https://www.dailymail.co.uk/news/article-2268251/Macbook-battery-starts-Oregon-student-flat-igniting-mattress-bedding.html>

<sup>53</sup> <https://www.nbcwashington.com/news/local/Laptops-on-Beds-Can-Lead-to-Fires-Safety-Officials-Warn-214839591.html>

<sup>54</sup> Kahn, Michael, et al.

<sup>55</sup> Kahn, Michael, et al.

<sup>56</sup> Kahn, Michael, et al.

<sup>57</sup> Kahn, Michael, et al.

<sup>58</sup> Kahn, Michael, et al.

<sup>59</sup> Kahn, Michael, et al.

<sup>60</sup> Elder, Gary. IEEE 1625 Helps Promote Safety and Reliability. *Power Electronics Technology*. April 2004.



overheated PCB traces, tracking across the PCB surface, overheated IC's, poor /resistive heating terminal connections, a poor design, misapplication, etc.<sup>61</sup>

2. In this case, some of the BMU components were functional, while others were damaged. Given that, and without additional proprietary information from the laptop and/or battery pack manufacturing regarding the design, function, testing, etc. of the subject battery pack, a failure of the BMU cannot be eliminated.
  3. In any case, the BMU is designed to protect from external electrical affects to the battery pack (overcharge, overdischarge, cell unbalancing, etc.). It is not designed to protect from an internal cell fault due to an internal defect, wherein the cell shorts internally.
- xix. Of note in this case, is the fact that the subject Li-ion cells were only a few weeks old. At this young age, the energy and recharge capacity of the cells was at its peak. A higher energy capacity of a cell can lead to more damaging outcomes when a cell fails. Further, internal cell defects leading to thermal runaway typically manifest themselves early in the life of a cell, and the subject cells fit this profile.<sup>62</sup>
- xx. As described above, the causes of Li-ion battery cell failures are many and varied. Cells that fail due to electrical stress share the same end result as those that fail due to an internal manufacturing defect, i.e. they overheat and vent. Due to the amount of damage sustained by the Li-ion battery cells and control circuitry, and a lack of propriety information, an exact determination of the particular failure mode has not been made at this time.
- xxi. However, in this case, mechanical damage, such as a puncture or impact damage to a steel cell can was eliminated as a cause of the fire. The computer was only a few weeks old and there is no evidence that the battery pack or cells were damaged prior to the fire. The battery cells were enclosed in a plastic housing to protect them from mechanical damage. Further, it is likely that the battery was rarely, if ever, removed from the laptop once it was first installed. The laptop was reportedly used in the bedroom and it was not known to be subject to damage or abuse.
- xxii. There is also no evidence that the subject Li-ion battery cells were exposed to the level of abnormal ambient temperatures required to cause a spontaneous, explosive failure. The temperatures required for that kind of event are typically on the order of 158°F to 194°F. <sup>63</sup> There was no evidence that the southeast bedroom ever saw temperatures that high.
- xxiii. In this case, a failure of the Li-ion batteries could ignite the available first fuels, including the battery pack, laptop housing, and/or the mattress. Typical mattresses are made of combustible materials, as mentioned previously. The materials of laptop housing are currently unknown without additional information from HP, but typical materials include UL V-rated plastics, which can stay ignited for 30 seconds or more, enough time to ignite the mattress and/or surrounding materials. Additionally, Li-ion battery cells can explosively vent and spread flaming/molten particles in a wide area, as occurred with one of the cells in this case.
- xxiv. The evidence shows that it is more likely that an internal failure of the laptop ignited the fire in this case.

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<sup>61</sup> Failure Modes of Electronics. Crownlite Mfg. Corp. Accessed 06 October 2014.

<sup>62</sup> Kahn, Michael, et al.

<sup>63</sup> Kahn, Michael, et al.

## CONCLUSIONS

Based upon our examination of the fire scene and evidence items, a review of relevant documents and photographs, research and analysis, the investigation to date, and our experience, education, and training, the following conclusions are presented with a reasonable degree of scientific probability:

1. The fire originated on the bed in the southeast bedroom of Apartment E101.
2. The fire was caused by an internal failure of the HP laptop Li-ion battery pack that ignited surrounding combustible materials.

JENSEN HUGHES reserves the right to amend or supplement any of the findings and conclusions presented in this report if new information becomes available.

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